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Interactive Comment

Interactive comment on "Climatic impacts of stratospheric geoengineering with sulfate, black carbon and titania injection" *by* A. C. Jones et al.

Anonymous Referee #1

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General Comments This article examines the climatic impacts of stratospheric particle injection with different particle compositions. The natural analogue to this geoengineering scheme is explosive volcanic eruptions which inject sulphate particles into the stratosphere. The volcanic injection of sulphate is extensively described in the literature and its effects on the climate, atmospheric dynamics, atmospheric chemistry (in particular stratospheric ozone), human and ecological health are reasonably well understood. To deliberately inject a non-sulphate material is inherently more risky due to the lack of accompanying research on the effect of the non-sulphate material on the above listed processes. However, if the non-sulphate material offers potential benefits compared to sulphate then it is worth evaluating their likely performance.

The article primarily investigates the climatic effect of the different particle composi-

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tions: sulphate, black carbon and titania. The main conclusions reached are that the use of black carbon is untenable due to the severity of the stratospheric warming. Titania is also shown to cause a stratospheric warming but the effect is smaller than black carbon. The required injection rates for titania and sulphur dioxide (leading to sulphate) are similar and hence with the negative effect of stratospheric warming and the greater unknowns associated with titania the article suggests that if stratospheric injection geoengineering is to be considered it should be with nature's choice – sulphate.

The authors state that aerosol microphysics is important but outside the scope of this paper. Clearly until the models can resolve the microphysics then the true aerosol effect will be unknown because of the large effect of microphysics on scattering efficiency and sedimentation rates. However, I accept that this remains a large challenge to the community which is currently unsolved and hence this paper cannot be expected to incorporate microphysics into the model if the schemes do not exist.

This is an interesting article which contains very useful data. The discussion on the climatic impacts under the conditions investigated is comprehensive. The experiments performed are sensible and allow for the successful inter comparison of the different particle compositions. On the whole the article is well written but some ideas are described too briefly and would benefit with some additional explanatory text. The article should be published once the comments below have been addressed.

Specific Comments

Abstract - The following statement is too strong "As injection rates for titania are close to those for sulphate, there appears to be little benefit of using titania when compared to the injection of sulphur dioxide." This statement should note that this conclusion is only with respect to the climatic impacts. At present, we do not know how non-sulphate materials compare to sulphate in their non-climatic impacts. For example, with respect to atmospheric chemistry; if a non-sulphate material shows less reactivity to stratospheric ozone, compared to sulphate, whilst providing similar climatic impacts

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then this material is potentially useful.

As the authors undoubtedly are aware the choice of RCP8.5 as the baseline scenario is a slightly controversial one. This gives the maximum likely climate forcing for the geoengineering to act against. Obviously, if the more generally assumed baseline scenario of RCP4.5 was used then the aerosol injection required would be lessened and the stratospheric warming effects of black carbon and titania would be lessened. The conclusions then reached might be significantly different. Some additional rationale should be provided why RCP8.5 was chosen. Furthermore, a qualitative description of the likely outcome if the gentler RCP4.5 scenario had been chosen should also be provided.

Figure 1 – why are there discontinuities between the short wave and long wave scattering and absorption data points? Does this suggest that the absorption and scattering properties are not accurately known? If so, what are the consequences of this? Can error bars be provided on these critical measurements?

Can a more direct comparison with the results of Ferraro et al (2011) be made? This paper seems to be at odds with Ferraro which states “The (stratospheric) temperature change from titania (Figure 2b) is approximately 30% of that from sulfate.” Be explicit about why the two papers come up with different results.

P30050 – It would be good to show how the 3 different injection rates were altered to maintain the TOA-RF balance (this could be included as a figure in the supplementary). Also how realistic is this approach to how geoengineering might be controlled in the real world? I imagine that in reality, the injection rate would be linked to a surface temperature over some spatial and temporal average. A brief comment discussing this point would be interesting. Furthermore, since you control the injection rate in the simulation is the following statement on P30053 justified? “. . .G3S exhibiting the greatest global mean cooling effect. . .”

P30057 – the following sentence needs additional explanation to make the point about

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the hydrological cycle clear "...produces a greater SW forcing at the surface which could further disrupt the hydrological cycle..."

P30058 – "hygroscopic growth is not represented in the BC and titania schemes" – state whether you would expect BC and titania to be hygroscopic. Would this likely make a significant different to the results presented?

P30059 – "Therefore, additional research is needed in order to understand the effects on atmospheric chemistry of injecting alternative aerosols." This work has already started with respect to titania see work by Tang et al. references provided at the bottom of page.

P30059 – The impact of geoengineered particles on health is interesting but is under developed. Even if the injected size distribution of the particles in the stratosphere could be maintained there is less chance of them being maintained in the troposphere as they sediment out. In particular, it seems unlikely that titania would still be in the ultrafine size range once they deposited. Hence it is unclear whether the NIOSH recommendations for ultrafine particles would have any relevance. However, it is an interesting section so should be retained but some caveats should be added.

Technical comment P30048 units for the scattering and absorption coefficients are wrong.

P30052 – Provide the TiO2 deposition rate along with the BC and SO4 deposition rates.

References

Ferraro, A. J., Highwood, E. J., & CharltonâĂŘPerez, A. J. (2011). Stratospheric heating by potential geoengineering aerosols. Geophysical Research Letters, 38(24).

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Interactive comment on Atmos. Chem. Phys. Discuss., 15, 30043, 2015.